COMPARISON OF MATRIX CONVERTER AND COMMON CONVERTER FOR INDUCTION MOTOR APPLICATION USING MATLAB

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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I declare that "*Design and Simulation of Matrix Converter for Induction Motor Application*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not currently submitted in candidature of any other degree.

Signature : …….

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ABSTRACT

Among the most desirable features in power frequency changers are simple and compact power circuit, generation of load voltage with arbitrary amplitude frequency, regeneration capability, and operation with unity power factor for any load. These ideal characteristics can be fulfilled by matrix converter (MC) which is become increasingly attractive for the AC drive applications. It has the potential to replace the conventionally converter. Matrix converter is a new type of direct AC to AC converter which converts input line voltage into variable voltage with unrestricted frequency without using an intermediate DC link circuit. MC uses the space vector modulation technique to control the input power factor which is the simpler method than the other control modulation. The objectives of the project are to implement the MC to control speed and torque of induction motor by using MATLAB Simulink and to design the common converter for induction motor application besides to compare the performance of the induction motor by using matrix converter and common converter. The simulation results of voltage and current waveform will be achieved if the project is implemented successfully.

ABSTRAK

Antara ciri-ciri yang paling dikehendaki dalam penukaran kuasa frekuensi elektrik ialah kuasa litar elektrik padat dan mudah, penghasilan voltan beban dengan sebarang frekuensi amplitud, kemampuan dalam pengahasilan semula, dan beroperasi dengan faktor kesatuan daya untuk sebarang beban. Ciri-ciri ideal ini dapat dipenuhi oleh penukar matrik (PM) yang menjadi semakin popular untuk aplikasi dalam pemacu arus ulang alik. PM ini juga mempunyai potensi untuk menggantikan penukar konvensional (PK). PM merupakan kaedah baru bagi menukarkan secara langsung arus ulang alik kepada penukar arus ulang alik dan juga menukarkan voltan garis input kepada pelbagai voltan dengan frekuensi yang tidak terbatas tanpa menggunakan rangkaian tengah litar arus terus. PM menggunakan teknik modulasi vektor ruang untuk mengawal faktor input daya dan ini merupakan kaedah mudah berbanding dengan modulasi kawalan lain. Tujuan projek ini adalah untuk melaksanakan PM pada motor aruhan bagi mengawal kuasa putaran serta kelajuan motor aruhan dengan menggunakan simulasi MATLAB dan untuk mereka penukar konvensional (PK) untuk aplikasi motor aruhan selain untuk membandingkan pencapaian motor aruhan yang menggunakan PM dan juga PK. Keputusan simulasi untuk voltan dan arus gelombang akan dicapai jika projek ini dilaksanakan dengan jayanya.

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LIST OF SYMBOLS

C_s	-	Snubber Capacitance
R_s	-	Snubber Resistance
Ω	-	Ohm
VA	-	Volt Ampere
Hz	-	Hertz
HP	-	Horse Power
F	-	Farad
H	-	Hendry
deg	-	Degree
V_{rms}	-	Root Mean Square Voltage
T	-	Time
V	-	Volt
A	-	Ampere
rpm	-	Revolution per Minute
Nm	-	Newton Meter

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LIST OF ABBREVIATION

MC	-	Matrix Converter
CC	-	Common Converter
DTC	-	Direct Torque Control
SVM	-	Space Vector Modulation
DC	-	Direct Current
AC	-	Alternating Current
PWM	-	Pulse Width Modulation
IGBT	-	Insulated Gate Bipolar Transistor
SVPWM	-	Space Vector Pulse Width Modulation
THD	-	Total Harmonics Distortion
V_{env}	-	Voltage envelope
VSI	-	Voltage Source Inverter
LC	-	Inductance Capacitance
RLC	-	Resistance Inductance Capacitance

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In many AC drive applications, it is desirable to use a compact voltage source converter to provide sinusoidal output voltages with varying amplitude and frequency, while drawing sinusoidal input currents with unity power factor from the AC source. The development of matrix converter started when *Alesina* and *Venturini* proposed the basic principles of operation in the early 1980's. Matrix Converter is increasingly becoming popular because it does not have any intermediate energy storage devices except small AC filters for the elimination of switching ripples. This converter fulfills all the requirements of the conventionally used rectifier/ DC link/ inverter structures and provides an efficient way to convert electric power [1].

This paper describes matrix converter by using space vector modulation technique implemented to the induction motor. The performance of the induction motor by using matrix converter will be compared with the performance of the induction motor by using common converter. The common converter consists of rectifier part which converts AC to DC and inverter part that converts DC to AC. The project is performed by using MATLAB Simulink and all the results will be analyzed.

1.1.1 General Introduction of Matrix Converter

Matrix converter (MC) is a new type of direct AC to AC converter which consists of 9 bi-directional switches, arranged as three sets of three so that any of the three input phases can be connected to any of the three output lines. The input terminals of the converter are connected to a three phase voltage-fed system, usually the grid, while the output terminal are connected to a three phase current- fed system, like an induction motor and the permanent magnet synchronous motor might be that requires variable voltage with variables frequencies. It is very simple in structure and has powerful controllability [2].

Since there is no DC link as in common converters, the matrix converter can be built as a full-silicon structure. However, a mains filter is necessary to smooth the pulsed currents on the input side of the matrix converter. Using a sufficiently high pulse frequency, the output voltage and input current both are shaped sinusoidal. The matrix converter is an alternative to an inverter drive for three-phase frequency control [3].

The matrix converter has several advantages over traditional rectifier-inverter type power frequency converters. It provides sinusoidal input and output waveforms, with minimal higher order harmonics and no sub harmonics; it has inherent bi-directional energy flow capability; the input power factor can be fully controlled. Last but not least, it has minimal energy storage requirements, which allows to get rid of bulky and lifetime- limited energy-storing capacitors [4].

But the matrix converter has also some disadvantages. First of all it has a maximum input output voltage transfer ratio limited to ≅ 87 % for sinusoidal input and output waveforms. It requires more semiconductor devices than a conventional AC-AC indirect power frequency converter, since no monolithic bi-directional switches exist and consequently discrete unidirectional devices, variously arranged, have to be used for each bi-directional switch. Finally, it is particularly sensitive to the disturbances of the input voltage system [5].

1.2 Problem Statement

The matrix converter is superior to the traditional VSI because of regeneration ability and sinusoidal input current. Therefore, it meets the stringent energy efficiency and power quality requirements of the new century. MC can be considered to be a direct converter, in this respect similar to a cycloconverter, because it does not employ a DC link and the output waveforms are composed switched segments of the input waveforms.

According to the advantages of matrix converter, this project comes out with the problem statements of common converter cannot fully control the input power factor. The implementation of the matrix converter to the induction motor needs a better speed and torque controller. To overcome these issues, the implementation of induction motor load in MC with the space vector modulation (SVM) applies as the control strategy of the input power factor as it is the most popularly switching. It allows the control of input current and output voltage independently.

1.3 Objectives

The objectives of this project are:

1. To implement the matrix converter to control torque and speed of the induction motor.
2. To design common converter for induction motor application.
3. To compare the performance of the induction motor by using matrix converter and common converter.

1.4 Scopes of Project

The several scopes that need to be proposed for the project is focusing on the performance of the induction motor through matrix converter using MATLAB Simulink with space vector modulation as control strategy. The project also will cover on designing the common converter circuit (AC/DC/AC) with the same induction motor as a load.

After that, the performance of the induction motor from matrix converter and common converter will be compared. In order to compare the both converters, the comparison of the matrix converter by using different load which are resistance and induction motor and the comparison of the performance of the induction motor from source through matrix converter and direct source will be done first.

1.5 Thesis Outline

Generally the thesis contains five main chapters and the details of each chapter are summarized as below:

Chapter 1 consists of introduction and overview of the project. The problem statement is mentioned together with the relevant objectives to overcome the problem. The scopes of the project are also explained.

Chapter 2 reviews the main idea of matrix converter for induction motor application from the previous researches. Literature review is crucial for every thesis not only to support the proposed title but also to for guidelines and references.

Chapter 3 covers on the methodology that been used to design the project. It also covers about the scope of the project where every step on how to approach the solutions to solve the stated problems. This chapter also focuses on the basic design

of matrix converter and common converter besides the space vector modulation technique in order to complete the project. The methodology of the project is summarized in the flow chart.

Chapter 4 explains details about the overview of the project by using MATLAB Simulink. The output waveform of the experimental results of the matrix converter will be discussed. The performance of the induction motor from matrix converter and common converter is compared. Besides, the performance of the induction motor by using different source and the comparison of matrix converter by using different load also will be analyzed before doing the comparison of the matrix converter and common converter. In this section, all the results will be explained and discuss briefly.

Chapter 5 contains the conclusion from the overall project. Future recommendations also stated in order to improve this project in the future undertakings.

CHAPTER 2

LITERATURE REVIEW

2.1 Previous Research

The research of the project is important for guidelines and references to obtain the results. The research is covered detail on the matrix converter and the implementation of matrix converter for induction motor application.

2.1.1 Matrix Converter-Theory and Simulation [6]

The theory of three-phase AC/AC converters, known also through their modem name, the matrix converter is presented. Analysis of the three-phase converter loaded by a passive R, L load and by an induction motor follows. The analysis was performed by means of the software package "Simulink", a dynamic system simulation tool. This simulation environment was found suited for straight forward modeling and simulation of the electronic converter and the electric drive. The switching angles needed to control the electronic converter are calculated within the same environment by means of "MATLAB".

2.1.2 MATLAB/Simulink Implementation for Reducing the Motor Derating and Torque Pulsation of Induction Motor using Matrix Converter [7]

The output voltages of the variable voltage and variable frequency voltage sources employing voltage source inverter is non sinusoidal. The output current of a variable frequency current source using current source inverter is also non sinusoidal. When the induction motor is fed by using these inverters odd harmonics will be present in the input supply, because of these inverters output voltage is non sinusoidal. This harmonics do not contribute the output power of the motor, they produce additional losses in the machine. This harmonic loss reduces the efficiency and cause derating of the motor. These limitations can be overcome by using matrix converter because of its unique feature is pure sinusoidal as output. The matrix converter is superior to inverter drives because of its regeneration ability and four-quadrant operation. Therefore it meets the stringent energy efficiency and power quality**.**

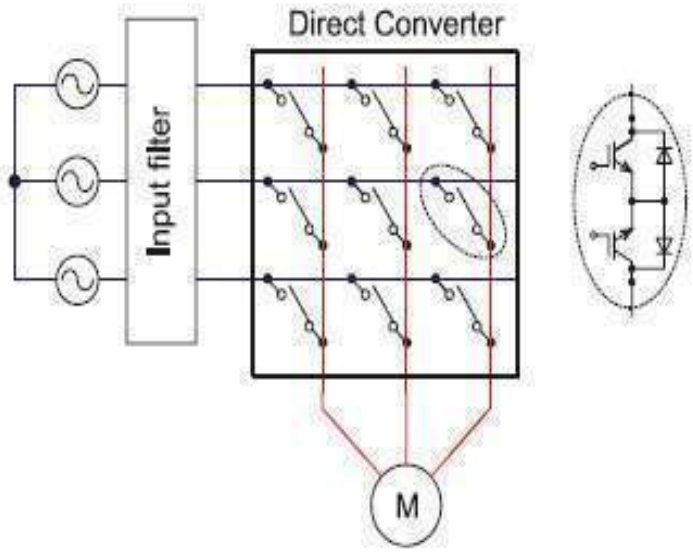
2.1.3 Simulation on Matrix Converter Fed Induction Motor DTC Drive System [8]

The Matrix Converter (MC) has received considerable attention in recent years because of its appealing operational characters. Namely, sinusoidal input and output waveforms, bidirectional power flow, controllable input power factor, absence of energy storage reactive elements, and compact size. Though MC has the lower voltage transfer ratio, the disadvantage can be eliminated by design the Matrix Converter Motor (MCM) to reach the nominal flux at the maximum voltage ration of MC to integrate the frequency converter, the induction motor into a single unit. The direct torque control (DTC) for induction motors has been presented to voltage source inverter (VSI). In this paper, Matrix Converter fed motor system is studied, which integrates MC and motor into a single unit, solves the problem of low voltage transfer ratio of MC, reduces the cost and increases the overall efficiency and the equipment ability. The mathematics model of Matrix Converter fed motor drive system in the static plane based on the fictitious link concept is given. A novel

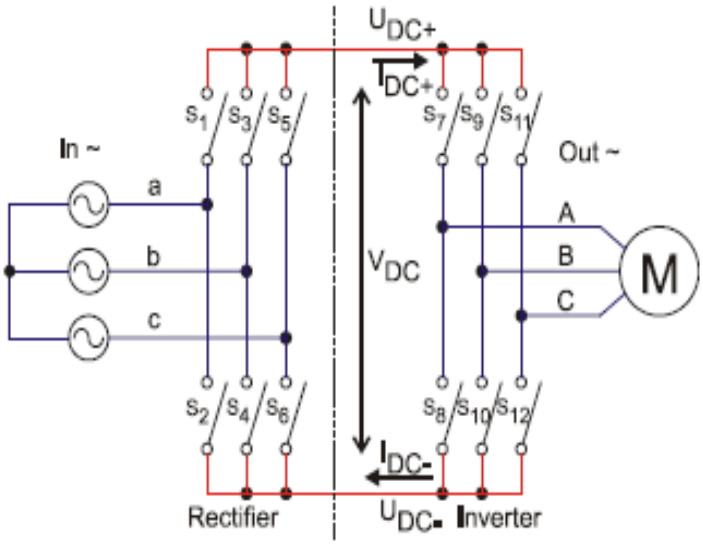
control method for Matrix Converter fed motor drive system is proposed which allows, under the unity input power factor and the required voltage vectors to implement the direct torque control (DTC). The simulations show that this way combines the advantages of Matrix Converter with the advantage of DTC.

2.1.4 Indirect Matrix Converter Based on Investigations of Field-oriented Control for Induction Motor [9]

The rectifier and inverter are used in vector control of induction motor. The most shortcomings are that exist a big capacitor and energy pass only from power sources to load. This paper details a novel matrix converter—indirect matrix converter. It is used in vector controlling research of induction motor and displaced for conventional inverter to supply power for induction motor. Because switches are bidirectional in the rectifier, it can realize bidirectional pass of the energy and decrease pollution of harmonic wave. Meanwhile bidirectional switches can act in zero current. Four step commutations do not be needed so that it decreases complexity of control process. In addition, indirect matrix converter which compared with direct matrix converter has the same advantages but it is simpler in controlling strategy. Matrix converter has a good prospect in frequency control system because it does not need filter capacitor and it has bidirectional energy pass, small harmonic pollution and a good controllability. Matrix converter can be divided direct matrix converter (DMC) and indirect matrix converter (IMC) in the structure. The main topology of DMC and IMC and the structure of bidirectional switches are shown in Figure 2.1.



(a) Direct Matrix Converter



(b) Indirect virtual DC-link matrix converter

Figure 2.1 Direct matrix converter (DMC) and indirect matrix converter (IMC) [9]